ICT driven pedagogies and its impact on learning outcomes in high school mathematics

Introduction

Some researchers and policy makers believe that achievement in high school mathematics is a good indicator of a nation's long-term economic prosperity but for many students it is not one of their favourite subjects at school (OECD, 2004; Slavin, Lake, & Groff, 2009; Wolfram, 2010). Reflecting on his school days, American actor Michael J. Fox recalled that he excelled in creative subjects like drama and music (Fox, 2010). In mathematics - it was a different story. Fox believed that the content was far too rigid and boring. As a consequence there was limited room for exploration. Fox's experiences can be explained by the fact that the content in the school mathematics curriculum is based on canonical bodies of knowledge (Kalantzis & Cope, 2008). It encompasses established rules which start with the learning of "times-tables" and concluding with "complex theorems and proofs" over time (p. 166). For some learners, mastering this knowledge in mathematics can be challenging.

While understanding the content is challenging, of equal or even greater importance is how the subject is taught. Australian television presenter Ray Martin recalled his experiences in mathematics classrooms in the first year of high school by pointing out that his teacher was "an absolute maths wizard but a dunce when it came to teaching" (Martin, 2009, p. 49). Martin's school report card said it all - he achieved 13% in the subject in the first term of high school. A number of investigations have concluded that there is a significant correlation between achievement in mathematics and the quality of instruction (e.g. Slavin, Lake, & Groff, 2009). In their extensive review of achievement outcomes of mathematics programs in middle and high schools, Slavin et al. concluded that initiatives which impacted on "daily teaching practices and student interactions" had a far greater chance to succeed (p. 839). As a consequence the choice of pedagogies and how it is implemented is critical to the success of teaching and learning mathematics (OECD, 2004).

On www.TED.com, Conrad Wolfram pointed out that the correct use of computers was the "silver bullet" that could make mathematics education work (Wolfram, 2010). Wolfram is the strategic director of the mathematical lab that is behind "the cutting-edge knowledge engine Wolfram Alpha". The findings of some studies concur with Wolfram's suggestion (e.g. Higgins, 2003). However, simply using computers does not make a difference to student learning outcomes. What matters is how these technologies are integrated in the classroom.

Given the rapidly evolving nature of ICT, there is a need for ongoing research to investigate the effectiveness of the chosen technology in the learning environment. This study reports on an investigation where ICT was integrated in a mathematics classroom. The participants in the treatment (N=25) and control groups (N=22) were students in the first year of high school (13-14 year olds). Pre and post results of standardised mathematics tests together with surveys and focus group interviews were used to investigate the impact of this initiative. In designing the learning environment for this study, the known barriers to technology integration were systematically addressed. Some of the research design variables that had diminished the findings of earlier studies involving pre, and post-tests were also addressed in this investigation.

ICT in Mathematics classrooms

How to learn mathematics? *The Program for International Student Achievement* (PISA) 2003 gathered information on how students in 41 countries applied strategies to succeed in mathematics (OECD, 2004). Research evidence was used to develop and gather data across four key constructs:(a) motivation; (b) self-related beliefs; (c) emotional factors, and (d) learning strategies. Collectively, these constructs overarched ten learner characteristics. Interest and enjoyment, instrumental motivation, attitudes to school and sense of belonging were characteristics of the motivation construct. Similarly, self-efficacy and self-concept characteristics informed the self-related beliefs construct. Anxiety was the only characteristic that was measured in the emotional factors construct. Learning strategies included three learner characteristics – memorization/rehearsal, elaboration and control strategies. While the OECD (2004) identified factors, which could influence learning outcomes, a number of ideas have also been proposed to enhance the teaching of mathematics.

Bell (1993) for instance, proposed that teaching concepts in mathematics should incorporate: (1) connectedness; (2) structure and context; (3) feedback; (4) reflection and review, and (5) intensity. Connectedness promotes the linking of existing and new concepts. Understanding the structure and context develops an understanding of the similarity between underlying patterns in related topics. Feedback is very important – it has to be instant so that any false manifestations of ideas can be corrected early in the teaching process. Students should also have an opportunity to review and consolidate new ideas. Intensity promotes rich experiences, which enable learners to engage in a range of problems and exercises of high quality (Bell, 1993). Some of the ideas proposed by Bell can directly influence learning as described by the OECD (2004).

In order to have a positive influence on how students learn mathematics, the pedagogical approach to teaching needs to be reviewed. While Bell's ideas (1993) can impact on learners, many mathematics teachers still rely on mimetic pedagogies that promote "authoritative content transmission and memorisation" (Kalantzis & Cope, 2008, p. 166). The learner is expected to receive the information and demonstrate "this acquisition by repetition" (p. 194). Drawing on the arguments of empiricist and rationalist theorists, Kalantzis and Cope pointed out that "by accepting canonical truths as presented, the learner is taking too passive a part in the knowledge process" (p. 166). As a consequence "knowledge remains abstract and distant, removed from everyday experience of the world" (p. 166). Mimesis dates back to the early days of how the texts of various religions were transmitted by the teachers to the disciples who regurgitated them later. Such an approach does not necessarily produce creative and self-motivated learners, and this impacts on learner motivation - as evident in the reflections of Michael J. Fox (2010) and Ray Martin (2009).

ICT presents new options and opportunities for learning mathematics. For this to occur teachers should be willing to review their pedagogies. However, as the TIMMS studies suggest, more needs to be done to systematically integrate these technologies in classrooms (Mullis, Martin, Gonzalez, & Chrostowski, 2004). Web applications on the Internet have created new opportunities for learners to develop their abilities in mathematics through active participation. The intelligence of some of the web applications enables them to act as th*e More Knowledge Oth*er (MKO) – as proposed by Vygotsky's Social Development Theory (Vygotsky, 1978). One of the key features of these applications is that they give instant feedback – very much like Skinner's teaching machines which were developed in the 1950's. Quality feedback is vital because it can have "powerful influences on learning and achievement" (Hattie & Timperley, 2007 p. 81). Video games give instant feedback - this is possibly one of the reasons that hooks players for extended periods. Similarly educational technologies have evolved significantly - the intelligence of some of the systems can do more than just respond to an input and generate an output. They too can give quality feedback to the users.

This potential for embedding web-based learning applications in science and physics has been reported in a few studies (e.g. Chandra & Lloyd, 2008; Chandra & Watters, 2011). A range of applications on mathematics (e.g. www.mathsonline.com.au, www.mathletics.com.au, www.khanacademy.org) are now available yet the "literature on the use of the Internet by Mathematics teachers in unguided non-experimental classroom situations is few and far between. There is limited information about Web-based pedagogies for teaching secondary school Mathematics, still less about effective ones" (Loong, 2011, p. 339). Studies focused on students in middle years of schooling (13-14 year olds, 8th and 9th graders) are even fewer.

The small number of studies on web-based learning reported in the literature suggested that it can influence learning outcomes in mathematics. For instance, in Taiwan, a remedial teaching application was found to be effective in improving learning outcomes of mathematics students in a junior high school (Wang, 2011). The assessment module used in Wang's quasi-experimental design study was focused on six mathematics concepts. In another study in the U.S., Nguyen and Kulm (2005) reported that students who had practiced learning about fractions and decimals on a web-based instrument performed better than students who were engaged in pen and paper practice. This study was conducted over three weeks. As a result of this experience, the students developed the perception that they were smarter in problem solving. Nguyen and Kulm acknowledged that while the findings of their investigation were promising, the short duration of their study warranted research over an extended period. They also suggested that the investigation should last for the whole school year. The possibility of the Hawthorne effect impacting on such short-term investigations should not be ignored (Diaper, 1990). The BECTA report: *The Impact of Technology: Value-added classroom practic*e (Crook, Harrison, Farrington-Flint, Tomas, & Underwood, 2010) also recommended that investigations into the impact of ICT on the learning practice should not occur in "a piecemeal manner in a corner of the curriculum" because "piecemeal approaches disturb(ed) the larger ecology of teaching, not just the local ecology of individual lessons" (p. 8).

This study

The current literature suggests that there is a need for further research to investigate the effectiveness of web-based learning in mathematics in middle years of schooling (Loong, 2011). Some applications can be effectively used to deliver learning outcomes. There is also a need to understand how these applications fulfill the needs of learners as identified by the OECD (2004). For this to occur in learning practices, web-based applications should be embedded in learning environments systemically and not in a piecemeal manner (Crook et al., 2010). More importantly, it should occur over an extended period (Loong, 2011). To address these issues, this investigation focused on ICT and its impact on learning outcomes of high school mathematics students. There were two research questions:

1) Is there a difference in the learning outcomes of students who are taught with and without ICT in mathematics classes?
2) If there is a difference, how much of the difference can be explained by the integration of ICT and particularly web-based applications?

Method

Participants

Year eight (first-year high school) students from an Australian high school took part in this study. The school was in an inner-city suburb. The treatment group (N=25) was one of two classes that had access to ICT during mathematics lessons. The control group (N=22) was taught predominantly through traditional pedagogies. The sample consisted of 25 males (Treatment -14, Control – 11) and 22 females (Treatment -11, Control – 11). The age of participants varied from 13 years to 14 years. The mathematics teacher in the treatment group also participated in the study. Pseudonyms are used to identify the participants in this paper.

Instruction conditions

At this school, strategic integration of ICT in the learning environment was viewed as a reform agenda, which had the potential to engage the net-Generation in classrooms (Oblinger & Oblinger, 2006). The school community believed that the integration had to be pervasive in the educational practice. ICT was integrated across all core-subjects in two out of eleven year eight classes. Mathematics was one of the subjects. In this yearlong study, we investigated the learning outcomes of two groups of mathematics students. Both these groups were statistically determined to be comparable. The teachers in each of the classes had more than 10 years of teaching experience. Before the school year, teachers were invited to participate in the ICT-driven school initiative. The teacher in the treatment group chose to teach with ICT while the teacher in the control group chose to use traditional pedagogies. The study reports on the first year of the ICT initiative at this school.

The treatment group had access to web-based applications throughout the year. In this group, traditional__ pedagogies_ were used alongside these resources. The control group were taught using traditional methods. Both groups were immersed in these environments from the first week of high school. The students in the treatment group had access to a range web-based resources – these included games, quizzes, videos, and Blackboard®. There was one web-based application (Web_X: pseudonym) which was commercially available. It had password-protected online access. Therefore, students could access it from their homes as well. The key features of Web_X were: (a) the teacher developed online question sets to suit his classroom needs; (b) it showed a fully worked solution to the users after one correct or two incorrect attempts; (c) it provided additional questions to consolidate understanding, and (d) it provided opportunities to the teachers for tracking students' performance.

The ideas proposed by Bell (1993) formed the basis of lesson delivery. This was achieved through the use of ICT and face-to-face interactions between the teachers and the students in the treatment group. Throughout the lesson, the balance of agency continuously shifted between the teacher, students, and web-based applications (Kalantzis & Cope, 2008). Such an approach facilitated three key interactions: teacher-students, students-students, and technology-student. The teacher's ability to facilitate and balance these interactions was critical in this environment.

Instructional context

Previous research has suggested that ICT integration has not succeeded in some learning environments because of a number of barriers. Access to resources together with skills and attitudes of teachers can serve as significant moderating variables towards student learning outcomes in such environments (Hew & Brush, 2007). For this reason, addressing these barriers appropriately was the first priority of this investigation.

In a literature review focused on barriers that impact on ICT integration, Hew and Brush (2007) reported that lack of resources was the most significant (40% of all identified barriers). To address this issue, the students in the treatment group had access to relatively modern software and hardware. Each student had access to a desktop computer in a custom-built classroom. The teacher had access to a data projector and an interactive whiteboard. The teacher's knowledge of teaching mathematics shaped the design of the learning activities. While his knowledge of the technology was still evolving, the teacher had a very favorable attitude toward its use in the classroom. A positive belief of teachers about using the technologies has been found to be more important than their technological expertise (Kim & Rissel, 2008).

Data collection measures

Data were gathered through qualitative and quantitative measures. Pre and post-tests formed the basis of the quantitative measure. Open-ended survey questions and interviews were used to gather data qualitatively.

Quantitative Measures.

Standardised mathematics tests were used to gather quantitative data. The quality of some of the studies done on pre and post-tests previously were diminished due to the lack of control of some variables (Joy & Garcia, 2000). These researchers believed that these variables should be adequately controlled if the results of such quasi-experimental designed research are to be meaningful (Table 1).

INSERT TABLE 1 HERE

In Joy and Garcia's (2000) investigation of studies done previously, less than half of the control variables that were considered important were adequately addressed. In this investigation, six out of the seven control concerns about variables were addressed as follows:

*Prior knowledge: Stu*dents in both groups had completed seven years of schooling and started the program at the same time.

*Ability: Stat*istically, there was no difference in the means of the PAT M*aths (pre-test) and N*umer*acy test data* (explained in the following section). This result suggested that the two groups were comparable in terms of ability.

*Teacher effects: Bot*h teachers (males) in this investigation had more than 10 years of mathematics teaching experience. While the teacher who taught the treatment group was highly "switched on" with technology-driven pedagogies, the teacher who had the control group favoured traditional pedagogies. This minimised teacher effects.

Time on task: For comparability between the groups, all students had 37 minute lessons each week for the whole year. The school year comprised of thirty-nine teaching weeks, which spanned over two semesters.

*Instructional method: Bo*th classes (treatment and control) focused on the same learning outcomes, content, assessment, and reporting procedures. The only difference was in the pedagogies used in the classrooms (Figure 1).

INSERT FIGURE 1 HERE

Pre and post-test measures.

(a) Numeracy test.

In the final year of primary school (Year Seven), students do a state-wide *Numeracy test*, which is administered by the Education Department. The purpose of this test is to monitor student achievement over time. The test also enables high school teachers to develop an understanding of their incoming primary school students in terms of their knowledge is some areas. The overall performance data from this *Numeracy test* was averaged for both the treatment and the control groups. A t-test showed that the difference in the class means (of the *Numeracy test*) were not statistically significant ($p<0.01$). This showed that the two groups of students (on the basis of the *Numeracy test*) were comparable in ability.

(b) *Progressive Achievement Tests* (PAT) in Mathematics.

The PAT gives a standardised measure of each student's mathematical ability across a number of topics. It is a multiple-choice test designed by the *Australian Council for Educational Research* (ACER). This test provides objective and norm-referenced information on students' level of achievement, their skills, and understanding of mathematics (Lindsey, Stephanou, Urbach, & Sadler, 2005). The test questions are spread across all the strands in mathematics (*Number*, *Space*, *Measurement*, *Chance and Data*, *Patterns and Algebra*) that is taught in Australian schools. The *PATMaths scale score* is based on the Rasch model and is derived from the raw scores obtained in the tests (Lindsey et al., 2005). It incorporates both achievement and the level of difficulty on the same scale. There is a strong relationship between achievement in these tests and school grades (Fogarty, 2007). *PATMaths5* was used as the pre-test measure and was administered at the start of the year (to both groups). All instructions as outlined in the testing conditions were followed. No calculators were allowed for the *PATMaths5*.

The PAT gives an indication of the progressive development of mathematics ability over the course of one year. The *PATMaths6* is designed to be a valid measure of comparison with scores on the *PATMaths5*. This was administered towards the end of the year to both groups.

Qualitative Measures.

Establishing the connection between educational technologies and learning outcomes is a challenge. Explaining any differences as a result of technology integration is an even bigger challenge. In this investigation students in the treatment group were asked a range of open-ended questions of their lived experiences of mathematics. It gave an insight into how the ICT initiative impacted on them. These questions were administered online to all students in the treatment group: (a) Did the use of technology make mathematics interesting? (b) Did the use of technology make mathematics lessons enjoyable? (c) Were the activities designed to your satisfaction? (d) Did Web_X make a difference to your learning of mathematics? Students were asked to explain their responses. Six students (of mixed ability) participated in focus group interviews. These students were asked to elaborate on their responses to these questions.

Data were collected mainly through unstructured interviews from the teacher (Denzin & Lincoln, 1994). This enabled triangulation of the data. The interview questions focused on his teaching strategies, use of technology, and the impact of this initiative on the students.

Data analysis

The quantitative data was analyzed in a number of ways. The Progressive Achievement Tests were marked manually and scored on the basis of the number correct in each strand and also on total raw score. The total raw score was also converted to the *PATMaths scale score* using the *norm tables* for each test (Lindsey et al., 2005). Means were calculated of the scaled scores for each class for comparison (California Department of Education, 2012). Using *SPSS*, a univariate analysis of covariance (ANCOVA) was performed to determine if significant differences existed between the means of pre (*PATMaths5)* and post-test (*PATMaths6)* scaled scores of the control and treatment groups. *Numeracy test* scores were used as the covariate. The approach taken here in analyzing the scores was adopted from a study undertaken in Louisiana elementary schools where the impact of ICT was investigated in students from low socio-economic backgrounds (Page, 2002). Three standardised tests were used in the study undertaken by Page to compare pre and post test scores. A t-test was also performed to determine if there was any difference in the means of pre (*PATMaths5)* and post-test (*PATMaths6)* scores of the control and treatment groups across the strands. Raw scores in each strand were used for this analysis.

Qualitative data were analysed using Nvivo and important themes were identified. Within this data, evidence was sought for the presence of practices that enhanced the teaching and teaching and learning of mathematics (Bell, 1993; OECD, 2004).

Results

Statistical analysis of the test scores showed some similarities and differences between the two classes (Table 2).

INSERT TABLE 2 HERE

While there was a small difference between the groups in the tests administered at the start of the year (*PATMaths5*), the difference in the means were not statistically significant. This was consistent with the difference in the *Numeracy test* scores. As explained previously, a t-test showed that the difference in the *Numeracy test* was not statistically significant. A difference in the results was also observed at the end of the year with the *PATMaths6* test. The treatment group achieved a higher mean than the control group. However, this difference was statistically significant ($p<0.05$).

PAT Maths test questions are spread across these strands - number, space, measurement, chance and data, patterns and algebra. In *PATMaths5,* there are no questions on patterns and algebra. Instead there is another series of questions on number which tests students' abilities to answer questions without a calculator (No calculators were allowed for any part of the *PATMaths5*). In this investigation the raw scores obtained in each of these strands (in each test) were converted to a percentage and compared between the two groups. An independent samples t-test was carried out for this comparison (Table 3).

INSERT TABLE 3 HERE

The treatment group achieved a higher mean in each topic. For *PATMaths5,* none of these differences were statistically significant. However, for *PATMaths6* the differences in the means were significant for three topics – number ($p<0.01$), measurement ($p<0.05$) and algebra ($p<0.05$). These results suggest that after a year's instruction the treatment group were achieving higher results (in three out of five topics) than the control group.

Discussion

Research Question 1: Is there a difference in the learning outcomes of students who are taught with and without technology in mathematics classes?

In this investigation the integration of technology in one of the classes (treatment group) is likely to have influenced the observed results. Both the year 7 *Numeracy test* (Treatment = 710.84, Control = 700.09) and the *PATMaths5* (Treatment = 71.56, Control = 67.85) tests suggested that there was no significant difference between the groups at the start of the year. This observation implied that there was comparability between the two groups. The means of the *PATMaths6* that was administered at the end of the school year suggested that the treatment group did better in the test than the control group (Treatment = 73.27, Control = 66.29) and the difference in the mean was statistically significant ($p<0.05$). The results also showed that students in the treatment group did better in three topics – number (Treatment = 78.40, Control = 60.43), measurement (Treatment = 71.50, Control = 57.60) and algebra (Treatment = 69.00, Control = 51.09). The differences in these means were also significant. While a similar pattern was observed in the two other topics - space and chance and data, the differences in the means in this case were not statistically significant. These variations could be due to: (a) the level of emphasis on these topics in class, and (b) the design of the activities. Concepts in a topic like space requires mental abstraction of 2D and 3D shapes and therefore puts a different cognitive demand on students. It could be due to variations in students' cognitive developmental stage (concrete vs. formal) as theorised by Piaget. Similarly, questions that require recall (e.g. Arrange the following numbers from smallest to largest) puts a different cognitive demand on the learner when compared to questions that needs students to demonstrate their abilities to apply the knowledge (e.g. interpreting time differences in a 24 hour train timetable). These would be areas of interest in further investigations.

On the basis of these results, it could be suggested that after a year's study and in the areas tested by *PATMaths5* and *PATMaths6,* the students in the treatment group were performing better in mathematics than the control group. This outcome was also reflected in school-based tests. It was consistent with Fogarty's (2007) suggestion that there is a strong relationship between achievement in PAT tests and school grades. Was this difference due to ICT? This is a difficult question. Feedback from the users was sought to explore this question further?

Research Question 2: If there is a difference, how much of the difference can be explained by the integration of ICT and particularly web-based applications?

Qualitative data gathered from the students and the teacher (in the treatment group) provided some plausible explanations for the observed differences in the students' results. Student motivation and varied teaching strategies driven by ICT appeared to have impacted on the students. The use of ICT in the classroom enabled students to not only "draw simultaneously on a range of resources" but also created an environment where students were motivated to do so (OECD, 2004, p. 114).

"Given the importance of mathematics for students' future lives", developing their interest in the subject is an essential prerequisite to life-long learning (OECD 2004 p. 117). Most of the respondents (69%) in this investigation believed that the use of ICT made mathematics more interesting. Jake explained that *a website or questions on an interactive screen was more exciting than a dusty old textbook.* A number of other students pointed out that it was a different experience. For example, *playing games* enabled students develop a better understanding of some concepts. It was also *fun* (Lewis).

"Interest in and enjoyment of particular subjects, or intrinsic motivation, affects both the degree and continuity of engagement in learning and the depth of understanding reached" (OECD, 2004, p. 117). The majority of the students (73%) also believed that ICT made the subject more enjoyable. Jake pointed out that ICT made the *learning stimulating*. A variety of strategies were used - for example games helped the students *understand the problems better* (Leanne). Learning was also enjoyable because students could work at their *own pace* (Roger), and it was *fun* and *challenging* (Lucinda). But as Mike pointed out, *I enjoyed the lessons because we got to learn how to use some very interesting technology*. On the other hand, for Mike *using computers has always been of to interest to* him. *Being able to use them in a learning environment has enabled me to enjoy learning more than I usually would. This has encouraged me to put in more effort and my grades reflect the work I have put in.* The teacher also noted a positive change in their motivation levels.

> *You know I think that it's like in anything, not just learning - it's in sports too. If you're interested in a sport you are going to practice it more – then you are likely to improve.*

In terms of the design of the lessons, 74% of the respondents believed that the learning activities were well designed in terms of clarity and the level of difficulty. Technological tools such as the electronic whiteboard were a help to learning because *tools like protractors and on screen rulers* enabled the teacher to *explain things on the computer/board with ease* (Budd). Activities on Blackboard® were *well designed and it enabled me to use a variety of different programs on the computer and the Internet [Saroi]*. While variety in the learning activities echoed positively through many of the responses - most also claimed that they were doable…*some of the activities were too easy but the majority were at a decent level of difficulty* [Jake]. The teacher deliberately implemented this strategy:

> *…I try and break it up [the lessons] too so that we're not just doing traditional mathematics work. So we'll get onto Blackboard® and I'll have a game based on the fundamentals…we compete and have a bit of fun and that breaks it up…I think it gives them a reason to learn what they are learning and they are going to use it to have fun. [Teacher]*

Web_X was the application which the students used the most. The majority of the students (80%) believed that this application made a difference to their learning. Various reasons were given to justify their answers. The program gave instant feedback - this was considered to be crucial in their decision. Bell (1993) considered this aspect to be important in teaching mathematics. From the students' perspective, this is a control strategy which is important to their learning (OECD, 2004). Learners become proactive and can regulate their learning. This according to the OECD delivers better learning outcomes. Students explained their reasons as follows: (a) *It gives you a second chance to change your answer if you get it wrong* [Khan]; (b) *It gave us instant acknowledgement of correct answers. This way I knew what to work on next* [Sarah], and (c) *The program was very helpful to me because it allowed me to instantly find out if I answered correctly and when I answered incorrectly it told me how I should have worked the answer out* [Savita].

For some students, the convenience of self-paced learning was viewed as important. Such an option can be a motivator for those students who are shy, withdrawn, or lack confidence in mathematics – it can also diminish students' anxiety. According to Hewitt and Scardamalia (1998) in a normal classroom environment such students avoid asking questions and therefore become passive learners. Personalised instruction with a *More Knowledge Other* (Vygotsky, 1978) can also have a positive impact on self-concept and student anxiety *(if you get it wrong you don't get embarrassed* - Vili*)* – both of these are important characteristics for learning mathematics (OECD, 2004). *Hints* enabled students to understand their work *more.* Such a convenience facilitated *revision* and was effective with *homework (Sarah)*. As a consequence it helped the students keep the *standards up* in the subject. Villi explained that one distinct advantage was that when you tried an exercise and *if you got it wrong it would show you how to work the question out and I always learnt from it.* Bell (1993) considered these aspects of reflection and review to be important aspects of teaching mathematics – it is also identified as an important memorization/rehearsal learning strategy (OECD, 2004). The convenience of doing this on a needs basis was important to Tim - *there were many different things to do. If you needed more practice you could login to the program.*

The students who did not believe that the program helped them with their learning identified technical issues with the software as a hindrance. *The program kept on having problems with loading and sometimes it would mark you wrong when you had the right answers* [*Peter*]. Ann explained her response as follows: *I said no, because it doesn't exactly explain how to do the question, and only gives one example*. For Rex, boredom was an issue: *It was a frustrating thing that was boring and did not help at all.* Perhaps, Rex had a different learning style and such an approach does not work for everybody.

Conclusions

The existing literature suggests that there is a need to develop a greater understanding on how web-based applications impacted on students in mathematics classrooms in pervasive practices. This investigation explored the impact of such an initiative on both – the learning outcomes and the participants. The data gathered in this yearlong study suggests that the use of ICT and in particular web-based applications did have a positive impact on students' and their learning outcomes. While such an approach did not enthuse all students, the majority of the students found it to be an engaging experience. Factors such as students' learning styles could be attributed to their dislike of this approach. This needs further investigation.

Technology may be the "silver bullet" that can reinvigorate student interest in the mathematics. However, this can only occur if a teacher knows when and how to integrate these tools. When this occurs, students see the value of such initiatives. A comment from Tabatha was significant; *I was close to failing in primary school and now I am doing better.* Similarly as Jake pointed out, *last year I was almost failing maths because I was bad at it. And this year I got my report card back at the start of the year and I had an A.* These comments from the participants highlight the significance of this initiative. Students found the approach to be interesting and as a consequence they enjoyed the experience. The environment added a degree of challenge but scaffolding through instant feedback ensured that engagement was sustained. The lack of such opportunities in classrooms where mimetic pedagogies are dominant leads to student disengagement, as was the case with Ray Martin. Instant feedback was one aspect of the learning tools which impacted positively on the students. Mathematics usually involves a series of logically connected steps. Knowing one step is often critical to progressing to the next step. For this reason, quality positive feedback is important because it builds confidence and point's students in the right direction. Such an opportunity also enabled students to reflect and review their work. From a teacher's perspective, in a typical classroom (with 25-30 students), instant feedback and repetitive feedback is not always possible. These aspects are also considered to be important strategies in teaching and learning mathematics. However, further research is warranted given that this study was based on an initiative which was in its first year. Understanding how teachers develop their pedagogical knowledge in such environments also needs further investigation.

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